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FOR IMMEDIATE RELEASE

## "Gang of Four" Receives \$500,000 Gruber Cosmology Prize for Reconstructing How the Universe Grew

*June 1, 2011, New York, NY*—Four astronomers who found a way to recreate the growth of the universe are the recipients of the 2011 Cosmology Prize of The Peter and Patricia Gruber Foundation. Marc Davis, a professor in the Departments of Astronomy and Physics at the University of California at Berkeley; George Efstathiou, the director of the Kavli Institute for Cosmology in Cambridge; Carlos Frenk, the director of the Institute for Computational Cosmology at Durham University; and Simon White, a director of the Max Planck Institute for Astrophysics in Garching, Germany, will share the \$500,000 award.



Marc Davis



George Efstathiou



Carlos Frenk



Simon White

The official citation recognizes the astronomers—nicknamed the “Gang of Four” by their colleagues and often collectively abbreviated as DEFW—for “their pioneering use of numerical simulations to model and interpret the large-scale distribution of matter in the Universe.” The Gruber Prize recognizes both the discovery method that DEFW introduced as well as the collaboration’s subsequent discoveries.

Davis, Efstathiou, Frenk, and White will each receive an equal share of the award, along with a gold medal, at a ceremony this fall. They will also deliver a lecture.

Astronomers have always told us what the universe looks like. Theorists have always invented ideas as to how it came to look that way. Not until the computer age, however, could scientists studying the evolution of the entire universe decisively match the gossamer of educated guesswork with the blueprint of observational evidence.

The particular evidence that motivated the creation of the DEFW collaboration came in the form of a 1981 Harvard-Smithsonian Center for Astrophysics survey of 2400 galaxies at various distances—at the time, an extraordinary census of how the heavens look on the largest scales. (Davis led the project.) What the CfA survey showed was an early hint of what is today called “the cosmic web”—galaxies grouped into lengthy filaments, or superclusters, separated by vast voids.

Theorists offered two competing ideas that might explain how matter could have coalesced in such a manner. Both theories took into account the presence of dark matter, a mysterious substance that astronomers in the 1970s had come to accept as a necessary piece in the cosmic puzzle in order to explain galaxy motions that otherwise would be violating the laws of physics. One candidate theory was “hot dark matter”—“hot”



because at early times the particles would travel at velocities approaching the speed of light. Such speeding particles leave behind the “regular” matter which makes up galaxies and so does not clump around them. The other candidate was “cold dark matter,” relatively sluggish particles that would fall together to build galaxy halos, dragging the regular matter along for the ride.

The Center for Astrophysics survey would allow astronomers to test these interpretations—but only if they could figure out how to model the evolution of the universe over billions of years.

Enter the Gang of Four. Although other astronomers had been working with  $N$ -body simulations—so called because they follow a number of points,  $N$ , each representing a concentration of mass—their code couldn’t handle a large enough  $N$  to represent large scales in the universe. Efstathiou, however, suspected that a code used to simulate ionic microcrystals would work. He succeeded in adapting it for cosmology, and Davis, Frenk, and White then used that code to demonstrate that a simulated universe based on the hot dark matter theory didn’t remotely match the CfA observations.

Then, in a series of five landmark papers from 1985 to 1988, Davis, Efstathiou, Frenk, and White showed that observations of galaxies, clusters, filaments, and voids were consistent with a simulated universe that had evolved under the influence of cold dark matter.

"The DEFW papers were instrumental in ushering in a new era where numerical simulations became a standard tool of cosmological studies," says Wendy Freedman, Crawford H. Greenewalt Chair and Director of The Observatories of the Carnegie Institution of Washington, and chair of the 2011 Selection Advisory Board to the Gruber Cosmology Prize.

Cold dark matter—or CDM—is today one of the two key components of the standard cosmological model. The other is the acceleration of the expansion of the universe, a discovery observers made in the late 1990s that DEFW’s simulations had anticipated. Scientists designate whatever is causing the acceleration with the mathematical symbol  $\Lambda$ , but it is more commonly known, in a nod to dark matter, as “dark energy.”

Nobody yet knows what dark matter or dark energy are. Yet as more extensive and more detailed observations of the universe have accumulated,  $\Lambda$ CDM has become the standard model of cosmology. Today the match between observation and theory indicates that the universe is composed of 4.6 percent “ordinary” matter, 23.3 percent dark matter, and 72.1 percent dark energy. Numerical simulations of the kind pioneered by DEFW show that a universe with this astonishingly precise yet remarkably strange composition does indeed develop structures which are a close match to those we see around us.

## Additional Information

The official citation reads:

*The Peter and Patricia Gruber Foundation proudly presents the 2011 Cosmology Prize to Marc Davis, George Efstathiou, Carlos Frenk and Simon White for their pioneering use of numerical simulations to model and interpret the large-scale distribution of matter in the Universe.*

*Cosmological simulations allow direct confrontation between observation and theory, and have transformed the way we conceive and visualize the growth of structure in the Universe.*

*The work of Professors Davis, Efstathiou, Frenk and White galvanized support for "cold dark matter" as the dominant form of matter in the Universe and has thus been instrumental in the crafting of our current cosmological paradigm.*



## Laureates of the Gruber Cosmology Prize:

- **2010: Charles Steidel** for his groundbreaking studies of the distant Universe.
- **2009: Wendy Freedman, Robert Kennicutt and Jeremy Mould** for the definitive measurement of the rate of expansion of the universe, Hubble's Constant
- **2008: J. Richard Bond** for his pioneering contributions to our understanding of the development of structures in the universe
- **2007: Saul Perlmutter and Brian Schmidt** and their teams: the **Supernova Cosmology Project** and the **High-z Supernova Search Team**, for independently discovering that the expansion of the universe is accelerating
- **2006: John Mather** and the **Cosmic Background Explorer (COBE) Team** for studies confirming that our universe was born in a hot Big Bang
- **2005: James E. Gunn** for leading the design of a silicon-based camera for the Hubble Space Telescope and developing the original concept for the Sloan Digital Sky Survey
- **2004: Alan Guth** and **Andrei Linde** for their roles in developing and refining the theory of cosmic inflation
- **2003: Rashid Alievich Sunyaev** for his pioneering work on the nature of the cosmic microwave background and its interaction with intervening matter
- **2002: Vera Rubin** for discovering that much of the universe is unseen black matter, through her studies of the rotation of spiral galaxies
- **2001: Martin Rees** for his extraordinary intuition in unraveling the complexities of the universe
- **2000: Allan R. Sandage and Phillip J. E. (Jim) Peebles:** Sandage for pursuing the true values of the Hubble constant, the deceleration parameter and the age of the universe; Peebles for advancing our understanding of how energy and matter formed the rich patterns of galaxies observed today

The Prize recipients are chosen by the Cosmology Selection Advisory Board. Its members are:

**Jacqueline Bergeron**, Institut d'Astrophysique-CNRS; **Wendy Freedman**, The Observatories of the Carnegie Institution of Washington; **Helge Kraghe**, Aarhus University; **Ronald Ekers**, Australia Telescope National Facility - CSIRO; **Andrei Linde**, Stanford University; **Julio F. Navarro**, University of Victoria; and **Roger Penrose**, University of Oxford. **Owen Gingerich** of the Harvard-Smithsonian Center for Astrophysics and **Virginia Trimble** of the University of California, Irvine, also serve as special Cosmology advisors to the Foundation.

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The Gruber International Prize Program honors contemporary individuals in the fields of Cosmology, Genetics, Neuroscience, Justice and Women's Rights, whose groundbreaking work provides new models that inspire and enable fundamental shifts in knowledge and culture. The Selection Advisory Boards choose individuals whose contributions in their respective fields advance our knowledge, potentially have a profound impact on our lives, and, in the case of the Justice and Women's Rights Prizes, demonstrate courage and commitment in the face of significant obstacles.

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The Peter and Patricia Gruber Foundation honors and encourages educational excellence, social justice and scientific achievements that better the human condition. For more information about Foundation guidelines and priorities, please visit [www.gruberprizes.org](http://www.gruberprizes.org).

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### **Affiliation with International Astronomical Union**

In 2000, The Peter and Patricia Gruber Foundation and the International Astronomical Union (IAU) announced an agreement by which the IAU provides its expertise and contacts with professional astronomers worldwide for the nomination and selection of Cosmology Prize winners. Under the agreement, The Peter and Patricia Gruber Foundation also funds a fellowship program for young astronomers, with the aim of promoting the continued recruitment of new talent into the field.

The International Astronomical Union, founded in 1919, is an organization of professional astronomers. It serves today a membership of more than 9,000 individual astronomers from 85 countries, worldwide. Information about the activities of the IAU is available from [www.iau.org](http://www.iau.org).

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For more information on the Gruber Prizes e-mail [media@gruberprizes.org](mailto:media@gruberprizes.org) or contact Bernetia Akin at +1 (340) 775-4430.

Media materials and additional background information on the Gruber Prizes can be found at our online newsroom: [www.gruberprizes.org/Press.php](http://www.gruberprizes.org/Press.php)

By agreement made in the spring of 2011 the Gruber Foundation has now been established at Yale University.